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The limited effect of toroidal flow on mixing efficiency in 3-D spherical mantle convection.

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The stirring of heterogeneities by mantle convection is a key process in explaining geochemical observations, but to date most studies have been performed in only two-dimensional geometry.
If 3-D convection has only poloidal motion, then its stirring efficiency is similar to that of 2-D convection, [Coltice and Schmalzl, 2006], but the presence of toroidal motion could make a major difference because it can lead to chaotic stirring paths even in a steady-state flow [Ferrachat and Ricard, 1998].
Toroidal flow is mainly associated with plate motions.
Two previous studies have assessed the influence of steadystate present-day plate motions on mantle stirring [van Keken and Zhong, 1999; Stegman et al., 2002].
Here we instead study flows in which time-dependent plate tectonics is selfconsistently generated by the rheology in a spherical shell, similar to [van Heck and Tackley, 2008], and has a toroidal:poloidal ratio in the range observed for the Earth.

The stirring efficiency is evaluated using passive tracers. The velocity field is decomposed into poloidal and toroidal components, and by removing all or part of the toroidal component of the velocity field used to advect the tracers we control the amount of toroidal flow the tracers experience.
In this way the effect of toroidal flow on the stirring paths is isolated, for flows that are otherwise identical.
Several diagnostics are used to measure the efficiency of dispersion and stretching and their spatial variation as function of toroidal:poloidal ratio of the fluid flow.

Our results for all diagnostics show that the effect of varying the fraction of toroidal motion on mixing efficiency is limited, for both time-dependent and static flows, with its main effect being to slightly increase dispersion speeds.
However, when toroidal motion is completely removed, a significant effect is observed, namely a reduction in dispersion speed. This holds true for both time dependent and time independent flows.